SIMULATION OF THE HYBRID PROPULSION SYSTEM FOR THE SMALL UNMANNED VEHICLE

Filip Polak, Jerzy Walentynowicz

Military University of Technology, Faculty of Mechanical Engineering
Institute of Motor Vehicles and Transportation
Gen. S. Kaliskiego Street 2, 00-908 Warsaw, Poland
tel., +48 22 6837352 fax: +48 22 6839546
e-mail:fpolak@wat.edu.pl, jwalentynowicz@wat.edu.pl

Abstract

The paper presents a simulation model of an unmanned vehicle propulsion system designed and constructed at the Laboratory of Internal Combustion Engines WAT. The vehicle was modelled in the software environment AMESim. It is intended as a tool for modelling of mechatronic systems, and therefore it was possible to create a link between mechanical parameters such as gears, with elements from the fields of electrical engineering and electronics, such as electric motors and inverters. Presented undercarriage system modelled the platform with 6x6 and independent drive wheels. Presented model of the hybrid structure of a small unmanned vehicle and sub models driver module and the propulsion module battery charging electric current through a combustion engine (generator controls, the switching of electric current battery capacity following a drop below the desired value - for this calculation was 50% of battery capacity). Characteristics of parameters changes of sets are presented. Simulation study for two batteries of different capacities as an example of the synthetic driving test and analyzed the differences between the foundation and set of characteristics. It was found that the higher-capacity battery could provide a better change of speed.

Keywords: *unmanned vehicle, hybrid propulsion system*

1. Introduction

Modern military operations are held with the participation of an increasing number of unmanned vehicles. The development of such vehicles requires considering many specific requirements of vehicle, identification of the surroundings and control of the vehicle at a certain level of autonomy. The most important requirements of the vehicle include maximum dimensions and weight of the vehicle, its payload and protection against damage, quiet ride, and overcoming obstacles, high speed and manoeuvrability, the largest range of vehicle, as well as many other requirements for traction. The basis for determining optimum powertrain solutions should be model studies, carried out using mathematical models of hybrid drivetrain. The purpose of presented paper was to develop a mathematical model of the hybrid powertrain in AMESim environment and to verify compliance responses such model to set up the conditions of the vehicle.

2. Object for modelling

The modelled object is a hybrid drive system of a small unmanned vehicle of approximately 250 kg. It is a hybrid system configuration so called “Range Extender”, which is similar to the configuration of an electric vehicle equipped in combustion engine, with a power approximately 30% of the electric engines power. This enables the vehicle to use a generator for charging the batteries. Such a propulsion system corresponds to the construction of the serial hybrids. Similar solution was developed in 1986 in the Electric Power Research Institute in Palo Alto, California. Small generator (3kW), used in the electric vehicle (40kW power, volume 34kWh), doubled range of the vehicle. Increased generator power to 6 kW, enable to reduce the battery capacity to 17kWh [2]. Such an arrangement is known from vehicles as Chevrolet Volt, Fiat 500 EV, Suzuki Swift mini and others. They used a combustion engine with a power of approximately 16kW provides propulsion of the vehicle even if the battery of vehicle is fully discharged. This took effect in less dynamic performance of the vehicle.

In modelling process, assumption that the object will be small unmanned vehicle with six wheels independently suspended and six electric motors driving the wheels through gears and pulleys angular gears were made (Fig. 1). Electricity is supplied from the battery, shown as a cube on the left side, and the ICE (middle) drives the electric generator with permanent magnets. The controller receives a signal from accelerator pedal position, brake pedal, electric motors speed and battery voltage and then sends a command signal for braking and speeding up electric engines. To simplify the construction of a small vehicle, assumption that the turning will be implemented using different velocity of rotation of the wheels from left or right side of vehicle. Such a solution decreased the size of the vehicle, primarily used for operations in urban areas. In addition, there is a circuit, which examines the vehicle battery charge level. Properly programmed battery controller runs the power generator when the battery charge level drops below 50% and continue loading up to 99% charge level. This procedure is done in a loop and its parameters may vary depending on operator settings.

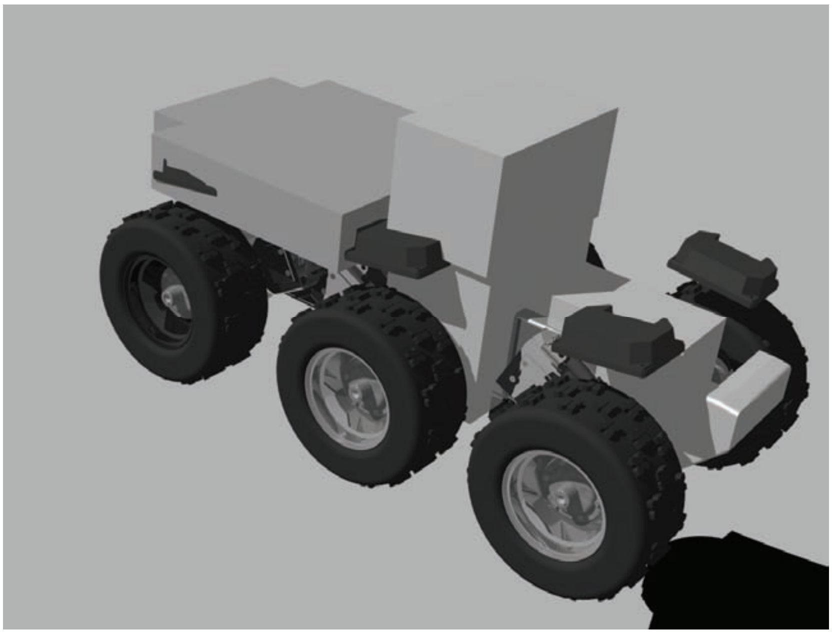

Fig. 1 A view of modelled platform

3. Vehicle simulation model

Simulation model of an unmanned vehicle was developed in the AMESim software. The package of these programs combines powerful computing system with tools for advanced static and dynamic analysis of each element or the entire system in a graphical environment. It was assumed that battery charging takes place in a two-state mode, i.e., the generator operates at a fixed speed, or is switched-off. Unlike as it took place in ordinary serial hybrids, where the engine speed is dependent on the power demand of the vehicle. Connecting diagram for the system is shown in Figure 2. Based on this structural model, a block model of the vehicle control system was developed and is shown in Figure 3.

Propulsion module, for which was created a separate supercomponent, consists of:

a) three-phase voltage inverter,
b) inverter controller,
c) PMS100 engine,
d) set of gears, belt (i = 2) and planetary (i = 7).

The principle of operation of the propulsion module is as follows: the port number one gives a rotational speed of the motor shaft PMS100 to inverter controller and to the main controller. The signal sent by the driver goes to the controller, and thus provides a voltage signal to the inverter, measured continuously in a current loop, keeping to not exceed the maximum value (I = 70A). The inverter converts DC power from ports 3 and 4 on the AC. Port 2 is a port, were vehicle wheels are connected.

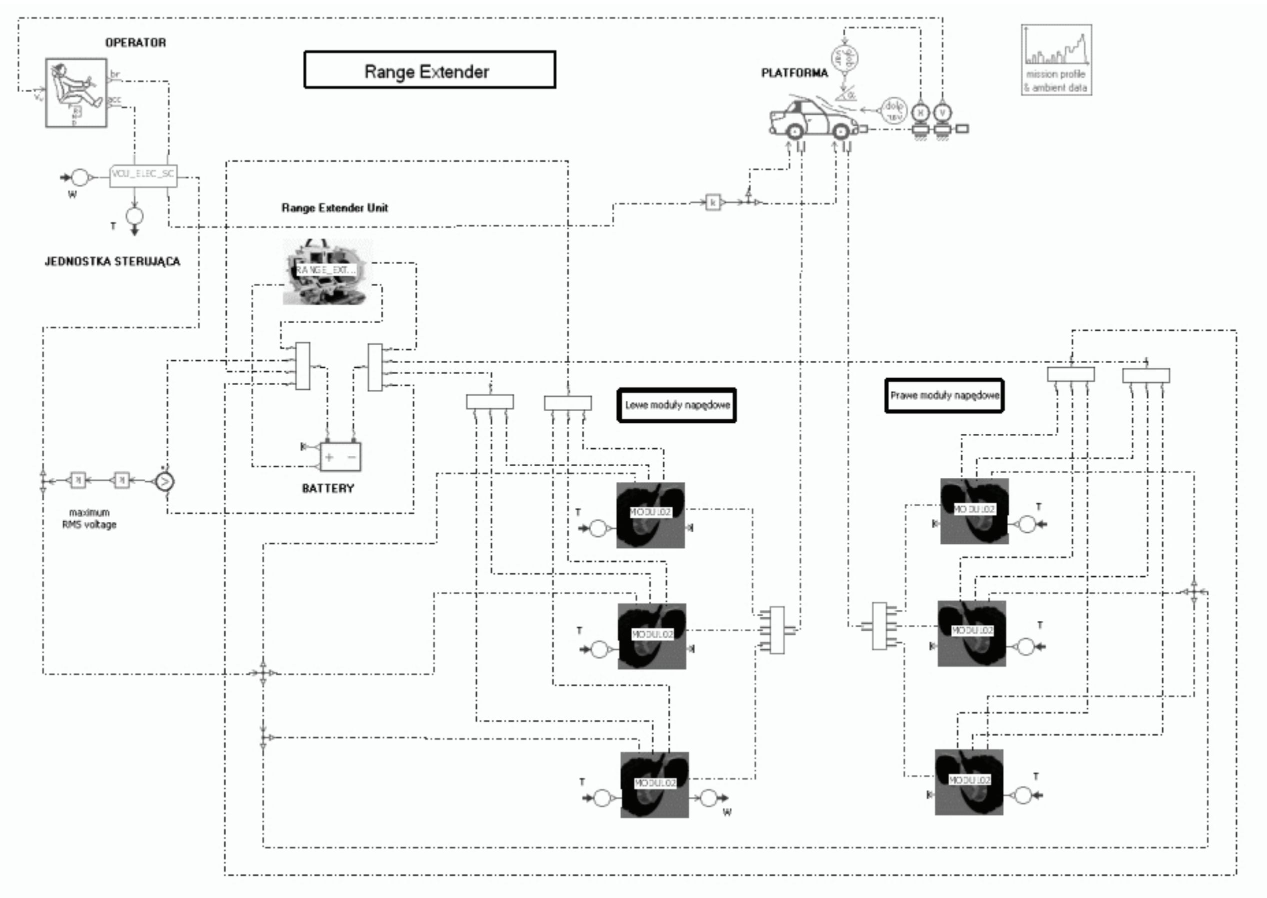

Fig. 2. Structural model of hybrid propulsion: 1 – driver/operator, 2 – mission profile; 3 – controller unit, 4 - battery, 5 - Range Extender unit, 6. - platform; 7- six propulsion modules

Described model of propulsion system is equipped with more sophisticated sub models. Those submodels are hidden under respective icons, enabling clear picture of entire vehicle. These include, inter alia:

• controller,
• drive module,
• Range Extender unit.

Range Extender Unit is a system that allows overcoming the after-distance rides more than is possible with only a battery-powered or allows to reduce the size of the battery. Range Extender unit offer smaller dimensions and less power relate to a series hybrid, but this is balanced by the time where unit runs continuously with constant power, regardless of whether the vehicle is parked in which the batteries are recharged, or in driving mode, when the unit provides power to the electric motors of vehicle and only missing part comes from the battery. State of charge of the battery is monitored by the Schmitt trigger, and if balance falls below the sets, the engine is switched on, and generator produces the necessary voltage to recharge the battery. This process takes place until the trigger signal, which in this case is set at 99% state of charge.

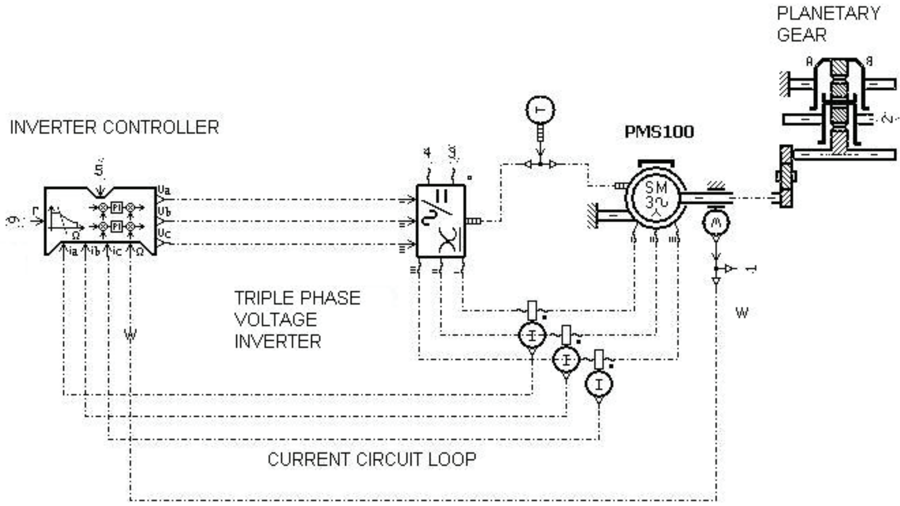

Fig. 3. Propulsion module scheme with in/out ports

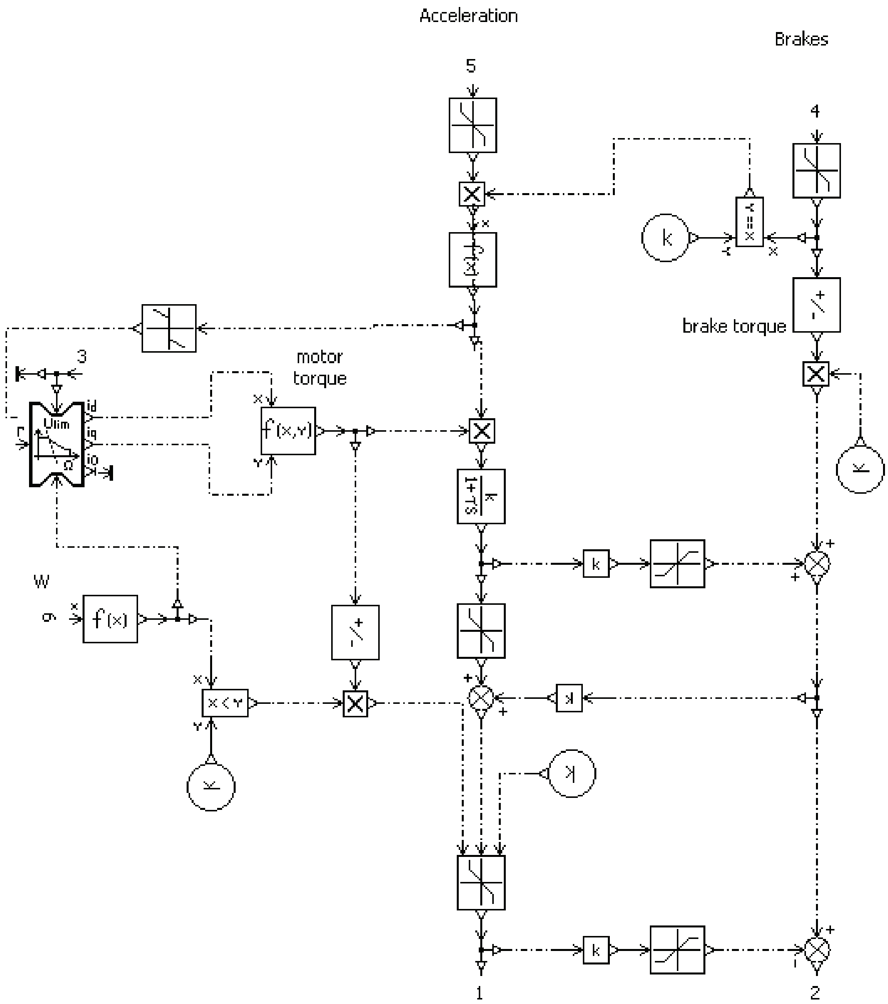

Fig. 4. Scheme of vehicle controller in AMESim

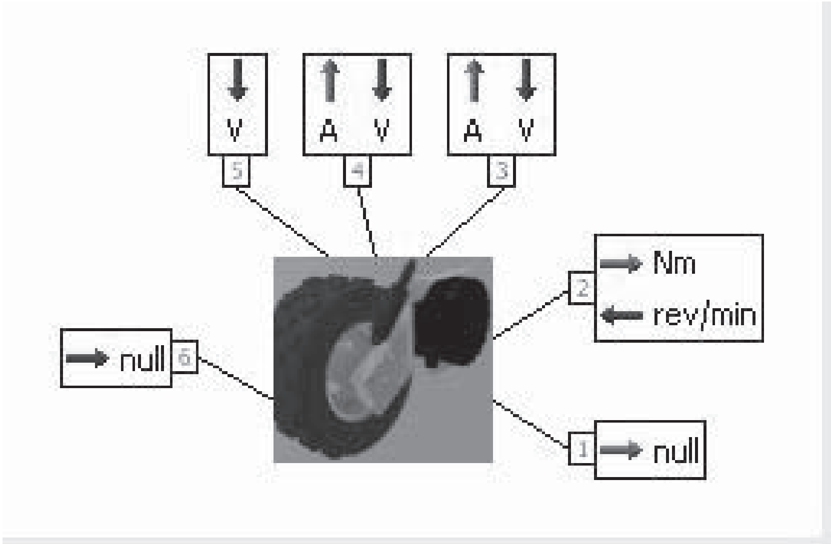

Fig. 5. Propulsion module with parameters

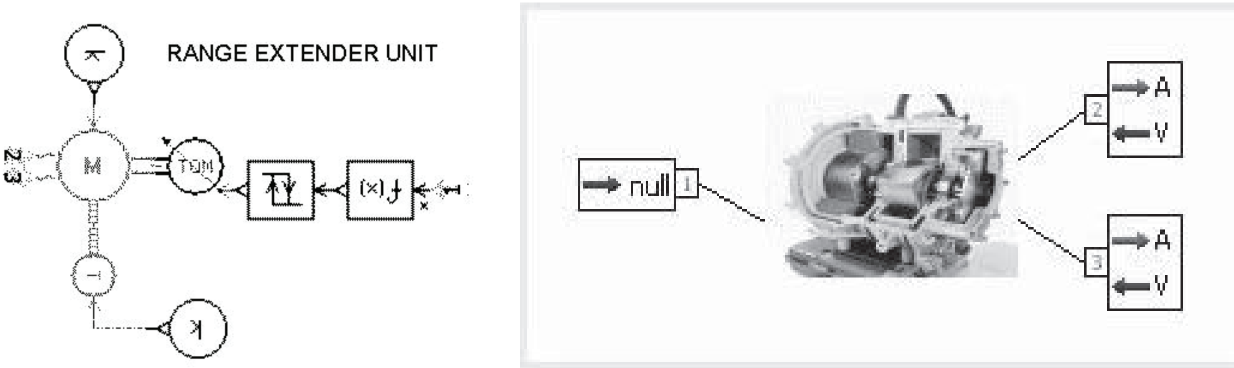

Fig. 6. Scheme of Range Extender unit and icon in AMESim software with in/out parameters

4. Components characteristics and simulation results

To simulate propulsion system for a hybrid vehicle, AMESim software, a program for mechatronic systems was used. To reconstruct the work of the entire propulsion system, digital libraries for each item that could be found on the platform was created. Program libraries did not have all the components of the platform. For this purpose, it was necessary to establish libraries for the following sets of hybrid propulsion system:

- battery;
- electric motor;
- generator;
- inverter;
- hybrid controller;
- tires of the vehicle;
- etc.

The verification of the simulation program was conducted on the example of synthetic simulations driving test, combined from the straight lines drawn from the mixing speed up, braking the vehicle and driving at a constant speed (Fig. 10). Test implementation result in increased vehicle changes demands in the range of the vehicle driving mode. Calculations were performed for a vehicle of weight 500 kg (250 kg of cargo) and a 55 percent initial charging two batteries with a capacity of 50 and 75Ah. The simulated speed of the vehicle is shown on the same graph. It is slightly overdue than the established line. The biggest differences between these two simulations are shown before the vehicle reaches maximum speed. In addition, vehicle momentary exceeds the maximum speed due to mass and thus inertia of the vehicle. Battery capacity used did not influence at the course of the acceleration of the vehicle.

Despite the difference in speed, the developed model allows a thorough analysis of motion, while the deviation between the assumed course and obtained will be further analyzed in the simulation tests. Figure 11 shows the course of discharging and recharging of battery with electric engines braking energy recovery, expressed as a percentage of charged batteries with capacity of 50 and 75Ah. It can be seen discharge during acceleration of the vehicle, much less discharge during cruising and charging the batteries under braking of vehicle. Increased battery capacity only results in a lesser degree relative of the final discharge of the battery.

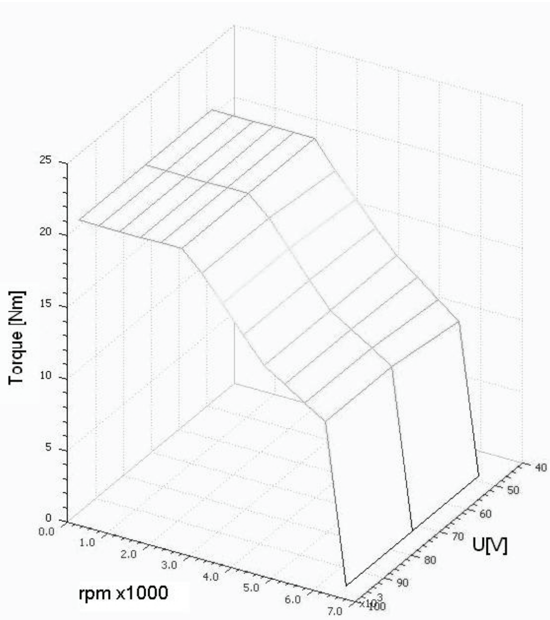

Fig. 7. PGS120 generator characteristics

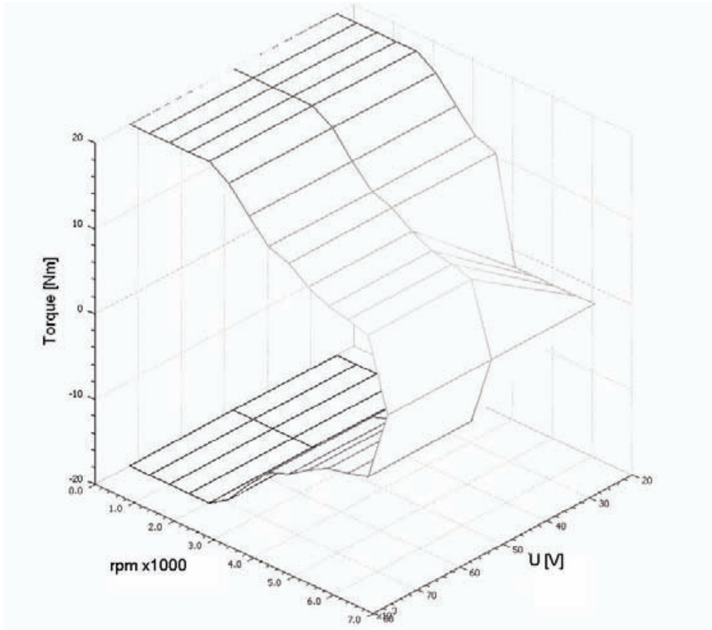

Fig. 8. PMS100 engine characteristics

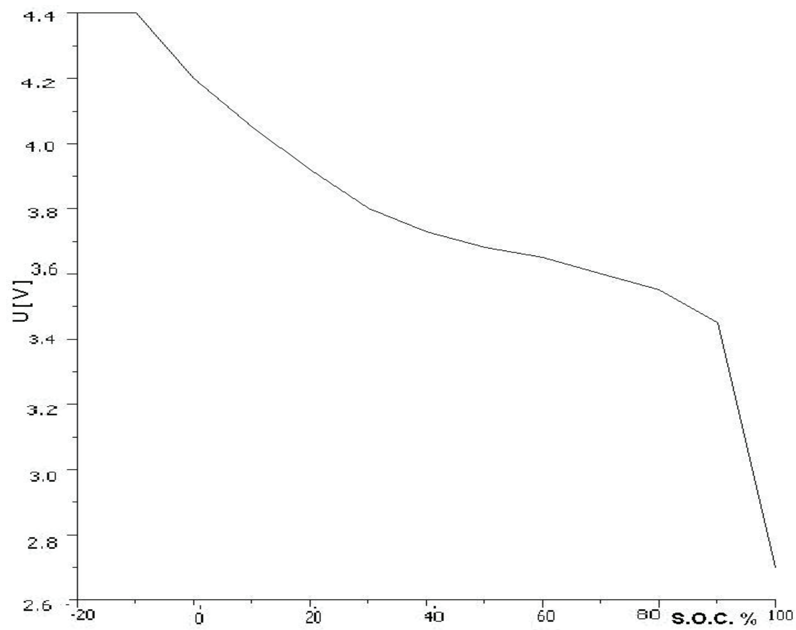

Fig. 9. State of charge of KOKAM battery

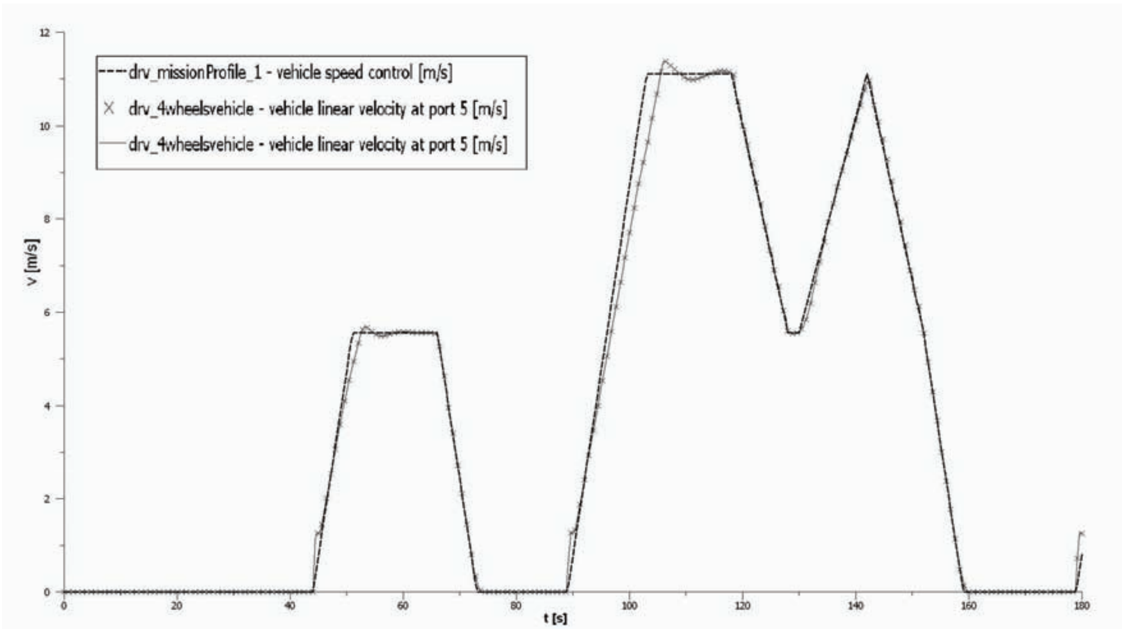

Fig. 10. Duty cycle of assumed and simulated vehicle speed

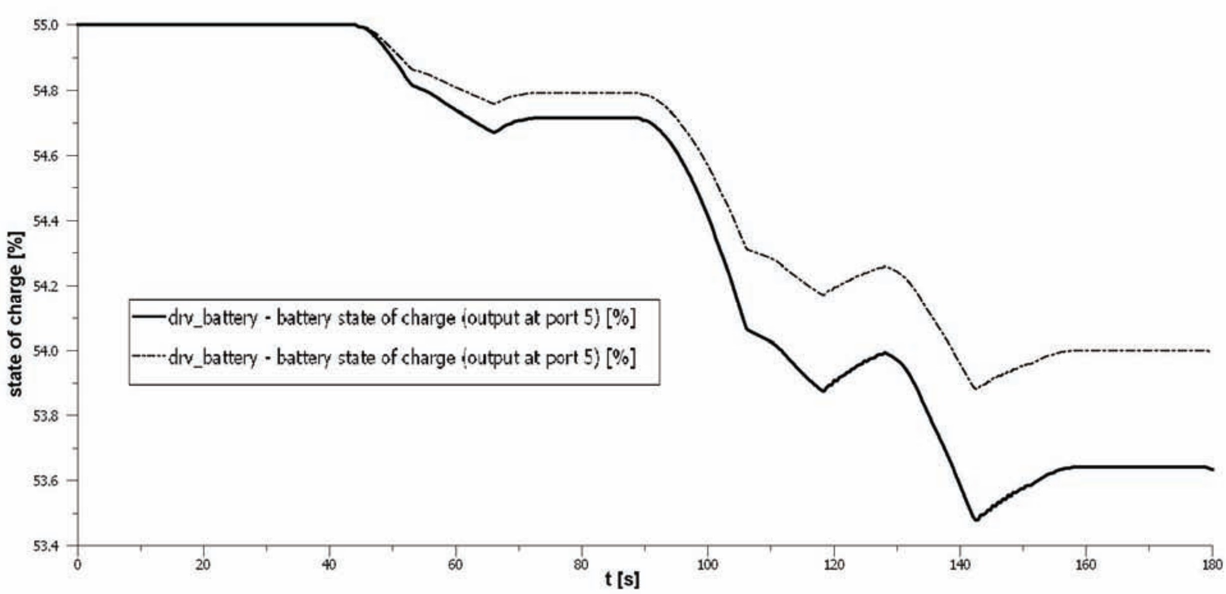

Fig. 11. Battery state of charge

7. Conclusions

1. Developed simulation models of hybrid small unmanned drivetrain platforms in the AMESim environment fulfil its mission and enable simulation of a hybrid drive system with sufficient precision to research on the selection of parameters optimization of such system.
2. The simulation model can analyze the waveform parameters of the vehicle, including, for example, the change in battery charge status, and the intensity of their load during braking or rechargeable batteries with on-board electrical generator.
3. Decreased acceleration of the vehicle propulsion system simulated in comparison with brief fore design was found. This problem will be solved during the optimization process, in which other

parameters of the system will be chosen, such as the supply voltage or the selection of gears in the transmission.

References

[1] www.avl.com
[2] Wouk, V., *Pojazdy z napędem hybrydowym*, Swiat Nauki, nr 12, 1997.
[3] www.lmsint.com
[4] AMESim help files
[5] www.perm-motors.de
[6] Polak, F., Walentynowicz, J., *Napędy platform bezzałogowych*, VII Sympozjum Naukowo-Techniczne SILWOJ'2010, Czernica 2010.
[7] Polak, F., Walentynowicz, J*: Koncepcja hybrydowego układu napędowego do pojazdu bezzałogowego*, VII Sympozjum Naukowo-Techniczne SILWOJ'2010, Czernica 2010.